6.0 Summary and Recommendations

6.1 Summary of MWTS Testing

The MWTS testing program was designed to simulate the performance of a pond-based chemical treatment system coupled with a treatment wetland. The field test of this treatment system sought to verify the three treatment effects:

1. TP reduction to < 10 ppb.
2. That the PACL phosphate floc was chemically stable with respect to phosphorous – i.e., that phosphorous would not re-dissolve from the solid phase; and
3. The wetland system would act as a polishing filter, and as a water quality conditioner, ameliorating the chemical changes induced by the chemical treatment.

The MWTS simulated a chemical treatment plant/settling pond coupled to a treatment wetland. Full-scale chemical treatment and settling pond systems are very common, and are used for a variety of water treatment purposes. The engineering is clearly defined. The basic engineering and processes of large-scale treatment wetlands are also sufficiently well understood to design a system for long-term effective performance. Therefore, an appropriate design for a full-scale chemical treatment/settling pond system coupled to a wetland for final conditioning of the settling pond effluent and final protection of the natural system downstream can be developed. A brief summary of key lessons learned are provided in this section and include:

1. TP was reduced to levels close to but above the 10 ppb target. Treatment effects conformed with the expected performance of the selected treatment chemicals on post EAA and STA waters.
2. Evaluation of the sludge showed that re-dissolution of P was not occurring. This verified that the settling pond system could provide effective P removal through floc settling.
3. The wetland system acted both as an ionic conditioning mechanism for chemically treated water and as a polishing filter for solids overflow.

A brief summary of the key lessons learned are provided in the following sections.

6.1.1 Project Planning & Startup

6.1.1.1 Critical Role of the SAC

The direction of the SAC was extremely valuable in setting the testing goals, the experimental design for the project, design of the chemical treatment units at the ENR, review of ENR pilot plant operations, and design of the pond treatment system. Additional SAC input would also have been valuable but was constrained by the project budget.

6.1.1.2 Choice of Experimental Design

The selection of the paired watershed design was a breakthrough solution to testing the MWTS. This design provided an elegant solution to what had been up to the first SAC meeting a complex testing regime that could not be implemented within the physical constraints of the test cells. Statistically sufficient data could not be produced using the classic replicated, nested statistical design originally envisioned due to the cost of constructing each experimental replicate. The paired watershed design allowed a single control and a single treatment to be tested statistically.

6.1.2 Chemical Selection

6.1.2.1 Initial Chemical Selection

Results of laboratory evaluations generally confirmed outcome from chemical screening done for other studies for alum. However, the results for ferric chloride, were confounded by apparent phosphorous contamination of the coagulant.

6.1.2.2 Selection of PACL

Concern over the use of alum (aluminum sulfate) due to the potential effects of sulfur loading on mercury cycling led the project team to test alternative aluminum salts. It was clear to the project team that if a sulfur-containing chemical were used, the mercury-associated issues would not be answered in time to meet the needs of the project. Thus, a cloud of uncertainty would remain regardless of other project results. Jar testing confirmed that PACL and alum performed similarly in regards to phosphorous removal for post-BMP and post-STA ENR waters. Project staff and the SAC concurred on a switch to PACL from alum. This allowed the MWTS program to move away from the complex and contentious Everglades mercury issue.

6.1.3 Baseline Calibration Period

The 6-month baseline was not quite long enough to provide an optimum statistical base for the paired watershed design calibration period. The availability of data collected by the District allowed an extended baseline data set to be constructed that provided a statistically robust regression relationship between each cell designated for treatment and the control cell. Each of the treatment designated cells was, using regression analysis, shown to have very consistent chemical behavior with respect to the related control cell.

6.1.4 Treatment and Verification Periods

6.1.4.1 Solids Recirculation

Solids recirculation was incorporated into pilot plant operation in order to simulate solids contact. The applicable design concept was that through solids contact the coagulant dose, as determined from standard jar testing procedures, can be reduced significantly. During plant operations no discernible benefit of the recirculation was detected under the designed conditions as assessed by the analyses done by the originally contracted lab. Laboratory analysis problems contributed to the inability to detect an effect of solids recirculation. Furthermore, the increased solids contact time was of little value at the coagulant dosages used, as determined from the laboratory testing for any dosage equal to or exceed the initially targeted dosing rate.

6.1.4.2 Solids Management

TSS was monitored in the treatment operations of the pilot units at the ENR. The monitoring points, presented in Exhibit 6-1, are as follows:

- Raw water inflow (A)
- Rapid mix zone (B)
- Flocculation zone (C)
- Clarifier effluent (D)
- Overflow to wetland (E)
- Solids storage tank and waste solids (F)
- Clarifier solids (G)

Solids production in a chemical treatment process can be directly influenced by the following measurable parameters: flow rate, raw water constituents, unit operation, polymer dose, and coagulant dose. During the pilot demonstration program, the flow rate was kept virtually constant throughout the project. The raw water TSS concentration also remained relatively constant. Solids recirculation from the sludge storage hopper to the flocculation chamber was the only operational parameter that was materially changed during pilot testing other than changes in the coagulant and polymer dose. The coagulant and polymer doses were basically either set to "high" or "low" dose rates. From pilot startup to early September the coagulant and polymer dose were both "high." It is also important to note that during this period settled-solids were re-circulated from the clarifier solids storage hopper back to the flocculation chamber. From early September to pilot shut down (late December) the coagulant and polymer dose were both "low." The dose rates for both chemicals were constant during these two different dosing regimes. Differences in solids production from the demonstration pilot project was directly proportional to these two dosing regimes. The settled sludge concentration however, did not significantly change between the two dosing regimes. Typical solids concentration in the sludge holding tank was 13,000 mg/L TSS (1.3 percent by weight).

During the "high" dosing regime, the coagulant dose was typically 69 mg/L Al203 (36 mg/L Al, 4 meq/l Al) and the polymer dose was typically 1.0 mg/L (active polymer). Approximately 60 percent of the solids generated during this period left the pilot unit as suspended solids in the outflow and were captured in the downstream wetland.

The other 40 percent of solids generated during this period were retained in the sludge storage tank.

During the "low" dosing regime the coagulant dose was typically 28 mg/L Al203 (14.5 mg/L Al, 1.6 meq/l Al) and the polymer dose was typically 0.5 mg/L (active polymer). Approximately 30 percent of the solids generated during this period left the pilot unit as suspended solids in the outflow and were captured in the down stream wetland. The other 70 percent of solids generated during this period were retained in the sludge storage tank.

Solids management operational procedures are typically negligible on the day-to-day performance of full-scale pond systems but had significant adverse impacts on pilot unit performance. The difference in solids-liquid separation efficiency between the two dosing regimes was attributable in part to the deleterious effects of solids recirculation during the high dosing regime. The efficiency may also have been affected by slower floc settling at the "higher" coagulant dose rates.

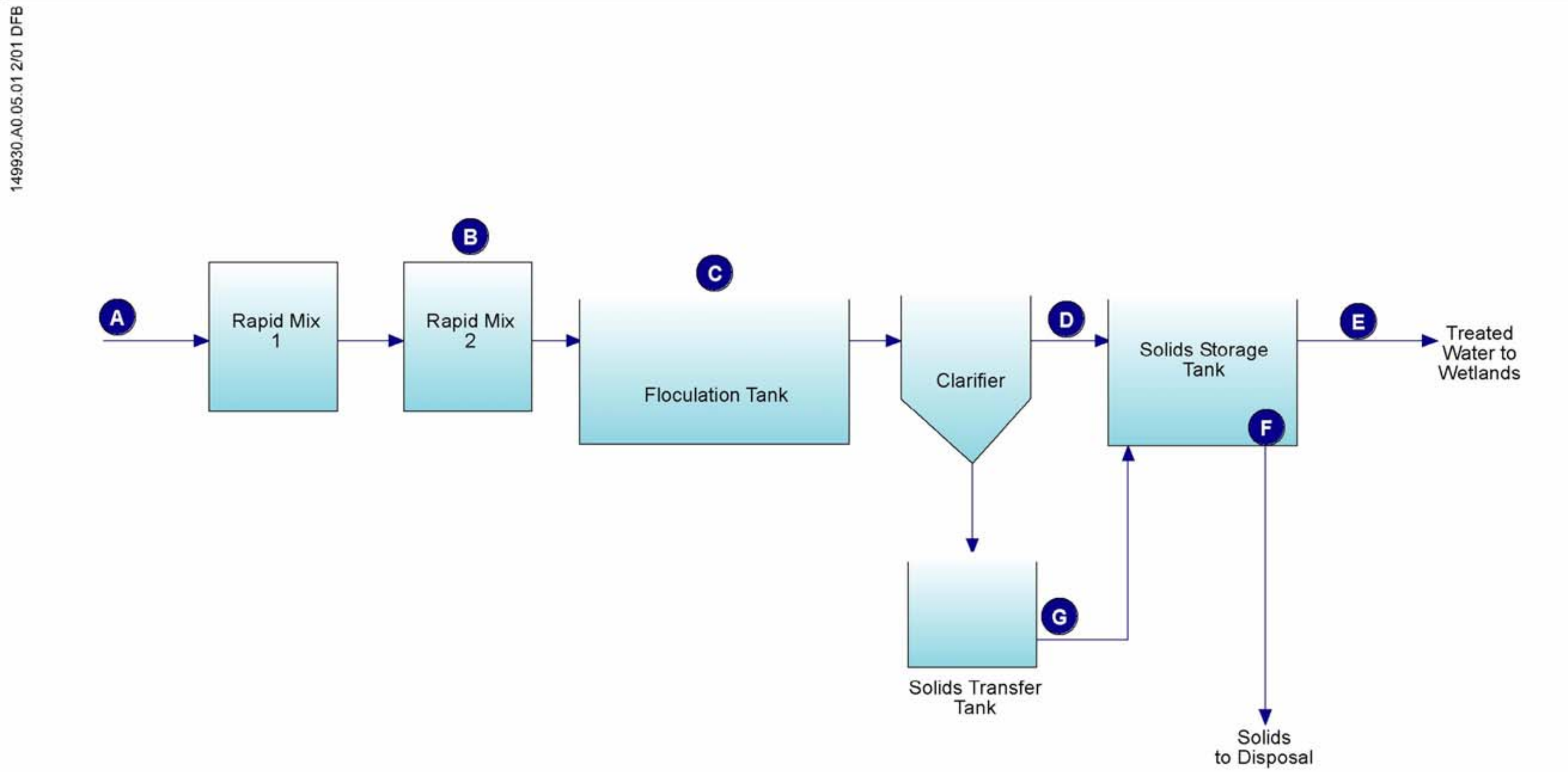

EXHIBIT 6-1
Pilot Unit Solids Monitoring Points

Under both dosing regimes, however, the majority of the solids overflow from the storage tanks to the respective wetlands is attributable to problems with the storage tank itself (see Solids Carryover section below).

A detailed description of the pilot plant design, plant evaluation, and plant operating records are provided as Appendices J, K, and L, respectively.

6.1.4.3 Solids Carryover

The overflow of floc from the solids storage tank to the wetland was significant. The solids storage tank was made necessary by the site constraints to the footprint available at the ENR site and would not exist in a full-scale design. The tank should not have been in the flow path; the clarifier effluent should have gone directly to the wetland. The transfer of waste solids from the clarifier and the solids transfer tank to the storage tank disrupted the sludge blanket in the storage tank causing significant re-suspension of solids. Every 1 to 2 days the sludge in the clarifier storage was allowed to flow to the bottom of the solids storage tank. That flow disrupted the settled floc causing re-suspension of solids and resulted over the period of the project in the passage of a large amount of the PACL floc into the wetland cells. The wetland cells were, however, very efficient at capturing this overflow. The overflow and the removal of the floc in the wetland represents effective overall system operation under a worst-case full-scale operation scenario.

Knowledgeable participants in the SAC meetings did not consider this overflow to be a flaw of the technology, but rather an outcome of the pilot treatment system configuration These participants concluded that the capture of these solids was a design issue that could be addressed in the design of the settling pond, pointing out that floc settling has been a recognized and practiced technology within the water industry for almost a century.

An analog to the settling pond concept is the chemical treatment of stormwater entering lakes, which has been in use in Florida for 15 years and is being more widely applied as time progresses. Alum stormwater treatment systems have been in operation in Florida since 1986. The first application was at Lake Ella in Tallahassee. Since then there have been treatment systems constructed for treatment of stormwater entering Lake Dot, Lake Rowena and Lake Lucerne in Orlando; Lake Osceola, Lake Virginia, and Lake Mizell in Winter Park; Lake Cannon in Polk County; Channel 2 Drainage Canal in Pinellas Park; Celebration Town Lake in Celebration; Lake Holden in Orange County; and Lake Tuskawilla in Orlando. Other projects are underway or under design in Winter Park, Orlando, Largo, Tampa, and Clearwater. (Harper et al., 1999). These systems inject P into the stormwater pipes and use the lakes as settling basins. Neither phosphorous release or aluminum toxicity has been detected at any of these sites. The lakes act to effectively and permanently settle the alum floc that is created.

6.1.4.4 Phosphorous Feedback

Potential feedback of dissolved phosphorous from the flocculated material was tested in the laboratory prior the pilot plant start up, and also in the field during pilot plant operation. Neither test detected any measurable release of phosphorous from the settled floc. Phosphorous release from settled floc is not expected to be an issue with aluminum salts if full-scale chemical treatment is used as part of the Everglades restoration system.

6.1.4.5 Coagulant Contamination

The iron coagulant was contaminated with a soluble organic phosphorous. Coagulants contaminated with P would be of great concern in light of target treatment levels of 10 ppb. Clean (phosphorous-free) sources of chemicals should be identified.

6.1.4.6 Laboratory Reliability

The accuracy of the original contract laboratory's phosphorous data called into question results for the pilot plant operations from startup in March through September 2000. It is clear that quality checks such as split-sampling among several laboratories are needed as a regular part of any restoration monitoring effort with such low chemical targets in order to evaluate laboratory reliability.

6.1.4.7 TP Removals

Data summaries show that over the final phase of testing, the PACL treatment at the north performed close to the 10 ppb target for TP, and the FeCl treatment resulted in outflow values in the range of 15 ppb. Out of the 11 PACL treatment outflow samples, seven had values of 2 to 12 ppb, the average of those seven outflow samples was 11.5 ppb, and the median TP value over the period was 12 ppb. For the FeCl treatment the median TP value was 16 ppb. Results from the STCs over the time period are less clear, but show the same pattern of phosphorous export from the wetland cells. So while the PACL treatment generally yields lower P values than the control cell, both typically have outflow concentrations that are higher than inflow.

TP and SRP outflow concentrations in both NTC-FeCl and NTC-PACL outflows were significantly lower than those leaving the NTC-Control. Average treatment period concentrations were approximately one-half those of the control cell. ANCOVA results showed significant reductions in the treatment cell regressions compared to the calibration period and control cell performance.

6.1.4.8 TN Removal

At both locations the inflow and outflow TN values are approximately equal for the control cells (NTC-Control, STC-Control). NTC and STC results show a treatment effect with lower wetland effluent [TN] for the treatments as compared to the controls. At the NTCs the PACL treatment reduces nitrogen to a greater extent than the iron.

The MTWS treatment significantly reduced Total Kjeldahl Nitrogen (TKN) in NTC outflows. TKN concentrations were reduced both in average concentration as expressed in significantly lower regression intercept and in the range of concentrations measured in the treatment period outflow compared to the calibration period and control cell performance. STC concentrations were similarly reduced in terms of average concentration, but a reduction in the range of concentrations was not apparent when compared to treatment and calibration period / control cell data.

6.1.4.9 Other Water Quality Parameters

Based on a comparison of treatment versus control outflow concentrations for the calibration and treatment period, the following trends were observed:

- Alkalinity—FeCl treatment caused a significant increase in alkalinity, while PACL treatments caused a significant reduction in alkalinity relative to the calibration period.
- Calcium—FeCl and PACL treatments caused a reduction in calcium concentrations.
- Chloride—FeCl treatment caused a significant increase in chlorides, and to a lesser extent, PACL treatment also increased chlorides.
- FeCl—FeCl treatment significantly increased iron concentration, while the PACL treatment significantly reduced iron values.
- Aluminum – aluminum concentrations in the NTC-PACL outflow were slightly (but not statistically significantly) greater than of the inflow or NTC control outflows. Aluminum concentrations in NTC-PACL were highest in the plant outflow, and fell between there and the outflow. The concentration of aluminum was greatest at the 1/3 station in all of the NTC cells. STC-PACL aluminum concentrations followed a similar pattern, with the outflow concentration not significantly greater than that of the inflow water.
- Sulfate—PACL and FeCl treatments significantly reduced sulfate concentrations in the NTCs.
- TDS—FeCl treatment raised TDS concentrations, while PACL treatment caused a significant reduction in TDS.
- TOC—Both PACL and FeCl treatments significantly reduced TOC levels.
- Color – Color was reduced by both NTC and STC treatments, compared to their respective control systems and the calibration period.

6.1.4.10 Ionic Conditioning

In both the calibration and treatment periods, little change in concentrations were seen in calcium, magnesium, sulfate, TDS, and TOC. Concentrations of alkalinity, pH, and chloride were stabilized by the marsh during the treatment period.

During the calibration period, NTC-FeCl, NTC-PACL, STC-Control, and STC-PACL showed an increase in aluminum at the one-third station, but aluminum concentrations dropped off after the one-third station. Aluminum levels were reduced by the marsh in STC-PACL during the treatment period.

NTC-FeCl, NTC-PACL, STC-Control, and STC-PACL appeared to be exporting iron at the one-third station for the calibration period. This trend continued during the treatment period in NTC-Control, NTC-PACL, STC-Control, and STC-PACL. Iron concentrations were at a maximum in the plant outflow and the outflow of NTC-FeCl during the treatment period. There is a clear drop in iron concentrations as water flows through NTC-FeCl.

Total phosphorous increased significantly between the marsh inflow and the one-third station in NTC-Control, NTC-PACL, STC-Control, and STC-PACL, after which the concentrations dropped off before reaching marsh outflow. Total dissolved phosphorous concentrations were not affected by the marsh. SRP concentrations dropped significantly in NTC-Control and STC-PACL. TKN values dropped significantly through NTC-FeCl and NTC-Control.